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ABSTRACT

This paper describes a 2-year collaborative action research project in which the focus was to investigate the effects of the use of "Hands-On Equations" mathematics manipulatives in an algebra class on students' confidence, interest in, and ability to solve and retain understanding of algebraic equations. The first phase centered on documenting and comparing approximately 120 urban students' reactions to and accomplishments during both manipulative and "textbook" approaches to learning algebra in their eighth-grade classrooms. The second phase of the study was a follow-up on these same students regarding their retention of the manipulative "algebra learning strategies" during their ninth-grade mathematics experiences. Data collection methods included surveys, student reflections, work samples and test scores, and interviews. In brief, findings from phase one indicated students' confidence, interest, and ability in solving algebraic equations were very high when working with manipulatives. In addition, results of a mandated corporation-wide standardized algebra test far exceeded the corporation's expectations. Includes examples of survey questions. (Author/AIM)

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A TWO-YEAR COLLABORATIVE ACTION RESEARCH STUDY ON THE EFFECTS OF A "HANDS-ON" APPROACH TO LEARNING ALGEBRA

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A TWO-YEAR COLLABORATIVE ACTION RESEARCH STUDY ON THE EFFECTS OF A "HANDS-ON" APPROACH TO LEARNING ALGEBRA

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This paper describes a two-year collaborative action research project in which the focus was to investigate the effects of the use of "Hands-On Equations"[1] mathematics manipulatives in an algebra class on students' confidence, interest in , and ability to solve and retain understanding of algebraic equations. The first phase centered on documenting and comparing approximately 120 urban students' reactions to and accomplishments during both manipulative and "textbook" approaches to learning algebra in their eighth-grade classrooms. The second phase of the study was a follow-up on these same students regarding their retention of the manipulative "algebra learning strategies" during their ninth-grade mathematics experiences. Data collection methods included surveys, student reflections, work samples and test scores, and interviews. In brief, findings from phase one indicate students' confidence, interest, and ability in solving algebraic equations were very high when working with manipulatives. In addition, results of a mandated corporation-wide standardized algebra test far exceeded the corporation's expectations.

Collaborative Action Research

Research suggests that collaborative action research, in which classroom teachers and university researcher work together in the investigation of classroom phenomenon, provides a medium for teachers to systematically look at the problems or questions they face in their classrooms in an effort to find practical solutions (Cardelle-Elawar, 1993; Miller & Pine). A number of goals of collaborative action research have been identified, including stimulating classroom reform, improving teaching and learning, providing opportunities for teacher enhancement, and generating theory and knowledge (Raymond, 1996). There is much debate about whether or not action research should be valued beyond its teacher enhancement and reform opportunities. Noffke (1994) contends that one of the contemporary challenges of action research is to address the question of whether findings from action research can truly contribute to the body of research on education and educational reform or whether action research must be considered a singular form of research with methodologies unique to the field.

Reported herein is a description of a two-year collaborative action research project in which an eighth-grade teacher, Marylin, questioned the worthiness of her efforts to teach algebraic concepts via manipulatives. Although the initial motivation for the study was to critique the quality of mathematics teaching and learning in Marylin's algebra classroom, the project reveals research findings worthy of consideration by the theoretical community as a welcome addition to the modest body of literature on the teaching and learning of algebra (see Kieran, 1992). What follows is a brief description of the project structure and results from the first phase of the collaborative mathematics study.

Motivation for the Study: Marylin's Dilemma

Marylin had a dilemma. Because her middle school had elected to implement an "algebra for all" program, she suddenly found herself, after teaching middle school mathematics for 22 years, faced with teaching algebra to a wide range of students, many of whom would not have normally been encouraged to pursue algebra. She was not confident that she would be able to efficiently teach algebra to all of the

[1] "Hands-On Equations" was developed by Dr. Henry Borenson.

students through a traditional textbook approach. Fortunately, she was afforded the opportunity to attend a workshop on teaching algebra through a manipulative-driven algebra program.

As Marylin began to teach the innovative program during the tenth week of school, she started to worry about whether or not the program was effective. Specifically, she was concerned that some students would become dependent on the manipulatives and might not fare well when faced with traditional teaching methods in future high school mathematics courses. She was also concerned about the depth to which students would learn algebra and how they would perform on the end of the year standardized algebra test required to be taken by all algebra students, particularly since her colleagues at the middle school and high school taught strictly via algebra textbooks and were skeptical of her hands-on teaching practices.

It was at this point that she met with Anne, a university researcher, to discuss ways to investigate the following questions: (a) How does the use of these mathematics manipulatives in an algebra class effect students' confidence and interest in solving algebraic problems? (b) How does the use of these mathematics manipulatives in an algebra class affect students' ability to correctly solve algebraic equations and (c) Will the students' retention of algebraic skills learned via manipulatives last beyond the eighth-grade experience?

Methodological Procedures

Phase One

This study had two phases, the first taking place during the 1994-95 school year. For the first nine weeks of the school year, Marylin taught in a non-manipulative style using the adopted textbook. Following this nine-week period, she implemented the 26-lesson manipulative program. In short, the materials in this program introduce students to a manipulative approach to solving algebraic equations, and guide them through an intermediate pictorial approach, culminating in engaging students in activities that relate the manipulative to the more formal "high school" algebra. The reader needs to be aware that students were allowed, and encouraged, to use manipulatives during quizzes and tests given during the manipulative program. The tests and quizzes were designed in a format that paralleled the manipulative instruction.

The subjects of the study include five classes of eighth-grade students, approximately 120 students, at a lower class, inner city middle school in Indiana. Data collection methods include an end-of-year survey (see Appendix), weekly student reflections, teacher observations and teacher reflections, student work samples and test scores, and a whole-class interview (conducted solely by the university partner). These interviews focused on students' confidence and interest in learning algebra when working with mathematics manipulatives versus working with a textbook.

Data about students' ability to solve algebraic equations were initially gathered through student work samples and student tests scores during both the "manipulative phase" and the "book" phase. Some students were also videotaped while demonstrating algebraic solutions during class time. Transcriptions of these videotapes serve as a verifying source of data on students' abilities in algebra. Additional data on

students' ability to solve algebraic problems was gathered from a mandatory standardized algebra test given to all eighth-grade students in the middle school at the end of the school year.

Phase Two

The second phase of the study took place over the course of the 1995-96 school year, during which time we continued our investigation of these same students who have moved on to high school. We were interested in ascertaining the "durability" of the results of the manipulative experiences in phase one. In March 1996, surveys were mailed to approximately 90 students who could be located. Only 19 completed surveys were returned. Of those who completed the survey, eight students indicated that they would be willing to participate in a one-on-one interview during the summer of 1996 to talk about the past two years.

Findings From Phase One of The Study

Test and Quiz Grades

We first compared overall class grade averages from the textbook phase to those earned during the manipulative phase. Table 1 shows these initial results. In each case, overall class averages were higher during the manipulative phase than the textbook page.

Table 1

A comparison of class averages during periods of textbook instruction and manipulative instruction.

	Class Average	
Class Period	Textbook	Manipulatives
1st	65%	82.38%
2nd	70.47 %	81.28%
3rd	75.07%	85.29%
6th	81.4%	87.82%
7th	72.16%	82.1%

In general, individual students scores were higher during the manipulative phase than during the textbook phase. Some of the differences were quite significant. For example, 23% of the students went from below "C" scores to scores of 70% or higher, and 42% of the students earned an average of "A" work on their algebraic work with manipulatives whereas only 14% earned "A's" during the book phase. On the other hand, 12.5% of students did not have higher scores during the manipulative phase. Of these students, 33% had below "C" scores during both phases and 60% had a percentage difference between manipulative and book phase scores of less than 5%.

It is difficult to conclude what these numbers tell us. Certainly for Marylin, the results are meaningful to her practice in that the percentages provided some indication that students could solve algebraic problems well with the aid of manipulatives. Thus, it was clear that many students were better

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able to demonstrate their abilities through the manipulatives and were able to show understanding of algebraic concepts via the manipulatives. On the other hand, these percentages also cause some concern that perhaps the students may have "needed" the manipulatives to show what they know. Also, since work with the book came before and after the work with manipulatives, it is unclear to what extent the manipulative experience influenced later textbook performance. Thus we were compelled to break down student scores further (see Table 2).

Table 2
A comparison of class averages during periods of manipulative work and textbook work before and after manipulative instruction.

	Class Average		
Class Period	Textbook Before	Manipulatives	Textbook After
1st	78.36%	82.38%	57.13%
2nd	77.82%	81.28%	68.93%
3rd	76.07%	85.29%	75.4%
6th	87.24%	87.82%	77.65%
7th	74.96%	82.1%	70.33%

Clearly, in every case the class average during textbook instruction decreased after the manipulative instruction period. As before, individual achievement varied. For example, 77% of the students showed a decrease in individual average on textbook work after the manipulative phase. Individual results varied from class to class. All of the students in the first period class showed a decrease, while only 48% of the students in the seventh period decreased. Of all students who showed a decrease, 47% of those students' scores decreased by more than 10% and 21% earned a score of "D" or less in both textbook periods.

Marylin was quite disturbed by these results. A primary concern was that the manipulatives had weakened the students' abilities to work algebraic problems without manipulatives. She also considered the possibility that the students had not retained the learning they had achieved during the manipulative phase. Another possibility was that students may not have been making the connections between the concrete learning and the more abstract learning. Also, it could be that the material in the later part of the textbook was more difficult than earlier material, resulting in lower scores. And yet another likely possibility was that students did not enjoy the work from the textbook as much work with manipulatives and thus, did not put as much effort into their work. Any or all of these conclusions could be valid. However, the real dilemma for Marylin became how did the students explain the reasons for the decrease and how could she change her practice to deal with these unanticipated findings? These questions formed the foundation of questions to ask the students during phase two.

Standardized Test Performance

At the same time Marylin was agonizing over the surprising class averages, an additional piece of data provided a positive twist. On the standardized algebra test given to all eighth-grade students at the

middle school, Marylin's students performed satisfactorily, far exceeding the expectations of the administration and colleagues. Approximately 80 % of Marylin's students correctly responded to approximately 60% of the test questions. Because test questions were worded and had to be solved in a traditional algebraic fashion, Marylin believed she had successfully helped students bridge the gap between concrete and the more abstract algebra, even though the comparative textbook data left some measure of doubt as to the degree to which students fully made the connections.

Phase One Survey Responses

On the first-year survey, students were asked a variety of questions regarding their interest in learning algebra. Only 68 of the 120 students returned completed surveys. Responses to the survey question, "How did you feel when you learned that all eighth-grade students would have to take algebra?", students provided answers such as:

> *I thought it was going to be really hard ... I didn't want to take algebra. I'd rather take basic math.... I felt a little scared....I felt that doing algebra in the eighth grade would be fun....I felt like "oh no" I'm going to fail this class....I had never heard of it, but glad I did....I felt kind of intimidated by it because I thought it was a high school course....Mad, because I [stink] at math.... I thought I was going to be grounded every time a report card came out.*

However, when asked how they felt about algebra after finishing the manipulative lessons, they expressed:

> *I felt that it was a neat experience and that it wasn't so hard after all....Relieved, algebra was a breeze ...I really liked it because it was the most fun....I kind of liked it because it got easier as the lessons went on....I felt that I had learned more by the manipulative....Very comfortable about algebra....Good, the manipulatives were fun and very helpful....I felt it was easier because some of the things we did in manipulatives we could transfer into our regular algebra....I found it easier than the book....I didn't want to leave the manipulatives, they were fun.... I proved I could when I thought I couldn't.*

When asked which approach to learning algebra they liked better, using the textbook or working with manipulatives, 91% of the students preferred the manipulatives. Explanations they provided included:

> *There was no homework...using your hands...it was easier and funner...I always scored high... they were easier to understand...it wasn't boring...it was new... we didn't read much...we did really hard problems...everyone got involved...the textbook was hard and skipped around a lot... working with things other than texts make you alive and ready to work... I learned quicker with the manipulatives...you could actually see what you were doing...*

Those who preferred the textbook explained:

> *manipulatives were too messy...with the textbook you didn't have to worry about putting things up...it was more organized*

Fifty-seven percent of the students expressed that they learned more algebra when working with the manipulatives. They suggest:

We spent more time on it and it was funner...made me want to learn more...we could learn faster...because you see how you get the answer... when you actually touch the problem it's easier...I did more problems with the manipulatives...

Those who said they learned more when using the textbook reasoned:

The teacher explained more to us...the book will always have more learning .....it was more in depth... because we were in the book longer...book explained more...doesn't take as long...more detailed...had more difficult problems...the textbook you could read the pages to understand...I remember it more...I learned more because we took notes and listened to lectures...

Conclusion

Thus far, the data suggest that most of the eighth-grade students performed better academically and expressed more positive attitudes about algebra when working with manipulatives as opposed to the text. However, many unanswered questions remain at the end of phase one. We are intrigued by the initial findings and look forward to learning more about the long-term effects of this innovative teaching approach as phase two unfolds.

Collaborative action research provides an additional layer of professional enhancement "results" beyond the findings related to the focus of the inquiry (Raymond, 1996). Engagement in the inquiry process impacted Marylin's practice by causing a great deal of informed reflection to take place. Marylin continues to question her mathematics teaching practice and actively seeks ways to investigate and document the successes and limitations of her teaching. Thus, not only did this action research study provide a window through which to critique the results of alternative methods of teaching algebra, but it also encouraged reflective mathematics teaching.

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Appendix

Examples of Survey Questions- Phase One

How did you feel last August when you learned that all eighth graders would take algebra?
How do you now feel about algebra at the end of the school year?
Rate your knowledge of algebra? (Check one) Low __ Medium __ High __ Explain your rating:
Rate your confidence in doing algebra? (Check one) Low __ Medium __ High __ Explain your rating:
Using Dr. Borenson's "Hands-On" Equations method, solve the following equation with the "pictorial" method and explain how you did it: $2x + x - x + 1 = x + 9$
Which did you like better?: (Check one) Using the textbook __ Working with manipulatives __ Explain:
When did you learn more algebra?: (Check one) With the textbook __ With manipulatives__ Explain:
What would you change about the eighth-grade algebra program?